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GAS-EJECTED FLOAT AND RECOVERY SYSTEM

by

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ABSTRACT. The retrieval of negatively buoyant exercise torpedoes from the ocean floor after sea-run tests is essential to the antisubmarine-warfare effort. A simple, self-contained nonelectrical recovery system carried in the torpedo exercise head is described. It includes a gas-ejected float that has surfaced from varying depths to 2,600 feet, bringing up a connecting nylon line and two marker balloons. Electrolytic corrosion of a magnesium-alloy disk provides the timing from launching to positive ejection. The accessories for recovery include the Retriever Mk 1 Mod 0 and a torque-limiting winch.

U.S. NAVAL ORDNANCE TEST STATION

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CONTENTS

NEGATIVE NUMBERS OF ILLUSTRATIONS

Fig. 1, LHL-P 24359; Fig. 2, LHL-P 24083-10; Fig. 3, LHL-P 24083-6; Fig. 4, LHL-P 24083-3; Fig. 5, LHL-P 24083-5; Fig. 6, LHL-P 24083-7; Fig. 7, LHL-P 24083-9; Fig. 8, LHL-P 24083-4; Fig. 9, LHL-P 24083-8; Fig. 10, LHL-P 23258-3; Fig. 11, LHL-P 23258-2; Fig. 12, LHL-P 23258-4; Fig. 13, LHL-P 23258-1; Fig. 14, LHL-P 24360; Fig. 15, LHL-P 24083-2; Fig. 16, LHL-P 24083-1.

INTRODUCTION

The torpedoes of today, designed to meet the requirements imposed by modern high-speed, high-performance submarines, may be negatively buoyant and must operate to increasingly greater depths. Thus it has become necessary to provide a way to retrieve exercise torpedoes from beyond diver-capability depths during development and evaluation sea runs. In addition to the monetary savings realized in recovering the torpedoes, access to the run data acquired by instrumentation in the exercise heads is imperative for design and performance evaluation.

PROJECT PREREQUISITES

A recovery device was required to provide either torpedo positive buoyancy or another effective method of retrieval from beyond diver-operating depths. Compatibility with all modes of launching was essential--from surface ship by slide launcher, tube, or rocket, or from aircraft. In addition, the designated project time limitation precluded the fabrication and testing of several concepts.

The goal was to provide sufficient positive buoyancy to raise a test vehicle with a negative buoyancy of 185 pounds.

POSSIBLE DESIGN CONCEPTS

Two former methods of recovery were considered and eliminated: An extender section and a float-out location marker. An extender section provides the volume-to-weight ratio necessary for positive buoyancy, but the torpedo dynamics are changed from those of a warshot configuration. A float-out location marker would not have the force to roll the torpedo over in the event the marker was pinioned to the ocean floor by the torpedo.

Two concepts were considered: (1) the provision of positive buoyancy to the torpedo by means of propellant-grain-generated gas or compressed gas, and (2) the positive ejection of a float that surfaces while carrying a connecting line to the torpedo.

Providing positive buoyancy to the torpedo was considered first because of the relative ease of recovery and the possibility of raising the torpedo before it sinks to a depth where the pressure would crush its hull.

To obtain the 200 pounds of buoyancy needed to raise a 185-pound negatively buoyant torpedo, a heavy and bulky grain would be required to generate the gas in a propellant-grain system, as well as a complex of igniter, power supply to the igniter, gas-cooling coils, and other space-occupying components.

To raise the torpedo with a bag-inflation system would require a volume of compressed gas at extremely high pressure. Such a system would be potentially hazardous to personnel and would involve design and operational difficulties.

Both systems would restrict the negative buoyancy of a torpedo to a predetermined value, and both would be potentially ineffective in the event that a leak in the torpedo and subsequent flooding caused an increase in the negative buoyancy.

A float system that ejects positively and surfaces while carrying a connecting line imposes no restriction on the degree of torpedo negative buoyancy, and can operate independently of all torpedo functions. Such a system can be used for the retrieval of many types of torpedoes and other underwater vehicles.

SYSTEM DESCRIPTION

The Gas-Ejected Float and Recovery System developed at NOTS is a self-contained, nonelectrical device that ejects a float carrying a nylon line from an 8-inch-diameter well that is cast integrally with a torpedo exercise head. Timing for system operation is provided by a magnesium-alloy disk that erodes at a rapid, predictable rate in a saline solution (Table 1, page 5). When the disk shears after having been weakened by electrolytic corrosion, the system is actuated. Compressed nitrogen is released into an ejection system (discussed under System Assembly and Operation) that frees the lid (see page 10) and forces the float from the torpedo so that it can surface while carrying the connecting line and two marker balloons.

If the negative buoyancy of the torpedo is less than one half the breaking strength of the nylon connecting line (Table 1, page 5), the torpedo can be retrieved by hauling in the line, with a torque-limiting winch controlling the tension. As an alternative (or if the negative buoyancy is greater), a Retriever Mk 1 Mod 0, to which a steel cable is attached, may be sent down the connecting line until it engages a compatible spear at the torpedo, thus forming a continuous steel cable for retrieval (Fig. 1).

The system is comprised of the float assembly with the marker balloons, plus the guide post, cable, and lid assemblies, with the Retriever Mk 1 Mod 0 and a torque-limiting winch as accessories.

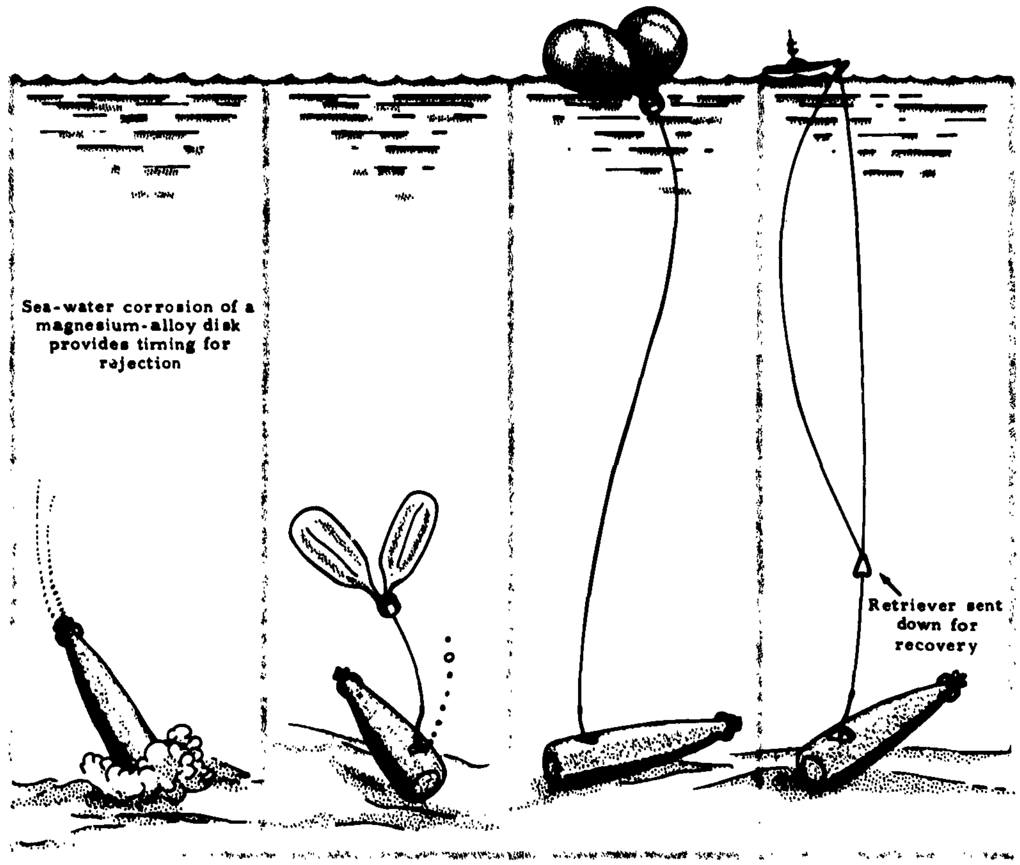


FIG. 1. System Operation.

The 13-pound float consists of four major subassemblies housed in an aluminum protective can: the pressure vessel assembly, the actuator assembly, the ejection assembly, and the spool assembly (Fig. 2).

PRESSURE VESSEL ASSEMBLY

The pressure vessel, consisting of a steel sphere to contain compressed nitrogen, and of two outlet tubes for balloon inflation, is housed in the upper portion of the aluminum protective can (Fig. 3). The can has an opening in the top through which the top of the pressure sphere projects, and an opening at the bottom to form a skirt.

Through the center of the sphere is an open cylinder that extends slightly beyond the bottom of the skirt. Additional float subassemblies are installed in and over the cylinder. It also guides the float during ejection.

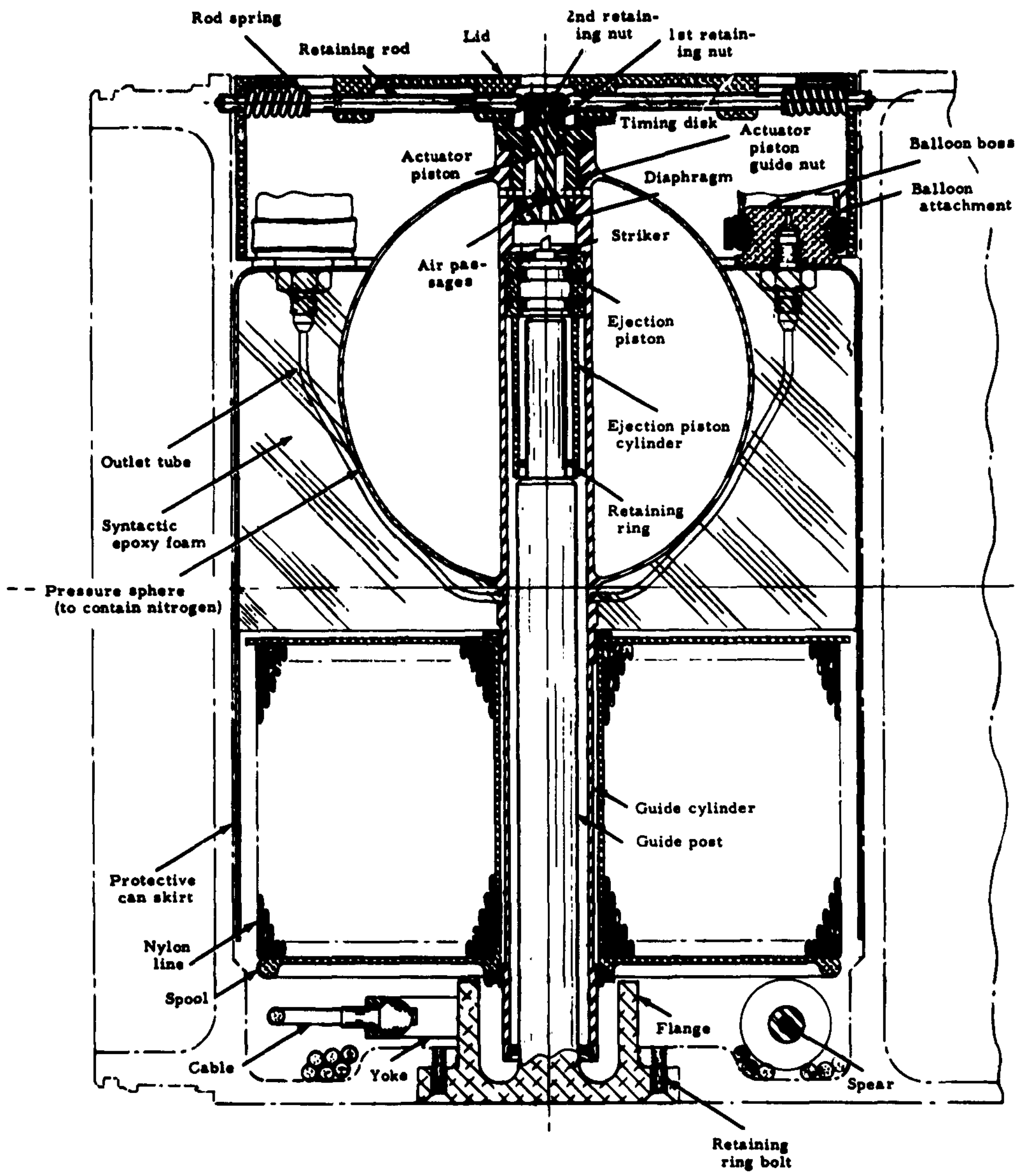


FIG. 2. Cutaway Drawing of Float System.

When the pressure vessel has been assembled, a syntactic epoxy foam[1] made according to a NOTS formula is poured around the sphere to a point just below the outlet tubes, thus providing buoyancy. The foam bonds to the sphere, to the outlet tubes, and to the protective can. An aluminum covering may be bonded to the bottom of the foam, if desired.

ACTUATOR ASSEMBLY

The actuator assembly (Fig. 4) is mounted in the top of the guide cylinder (shown in Fig. 3). A piston, with a diaphragm in the bottom to cover air passages, fits into a guide nut that serves as a piston bore and retainer. A magnesium-alloy disk, of the size required for nitrogen pressure and timing (Table 1), is placed over the stud of the actuator piston with the edges extending on to the guide-nut surface and secured with one of two retaining nuts.

TABLE 1. Float Parameters for Various Maximum Bottom Depths

Bottom Depth, ft	Timing Disk Thickness, in.[a]	Line Size Tensile Test, lb	Line Length, ft[b]	Nitrogen Pressure, psi	Torque-Test Readings, in-lb[c]
0 - 450	0.016	1,000	550	850	20
450 - 900	0.020	600	1,200	1,000	25
900 - 1,200	0.025	400	1,600	1,500	38
1,200 - 2,000	0.032	200	3,200	2,000	50

[a] Based on 30 ± 5 min operation time and 0.520-in. disk diameter. Actuation time may be extended by increasing disk diameter.

[b] Additional line may be required in strong currents to compensate for a larger catenary.

[c] Values are average. Torque values recorded after pressurization should be used to check pressure before launching. Values will vary due to differences in torque wrenches, friction of O-rings under pressure, and surface finish of the timing disk and guide nut.

[1] A syntactic epoxy foam is one in which the density and other physical properties are controlled by the percentage of lightweight material used in a plastic matrix.

FIG. 3. Pressure Sphere, Guide Cylinder, Outlet Tubes, and Protective Can.

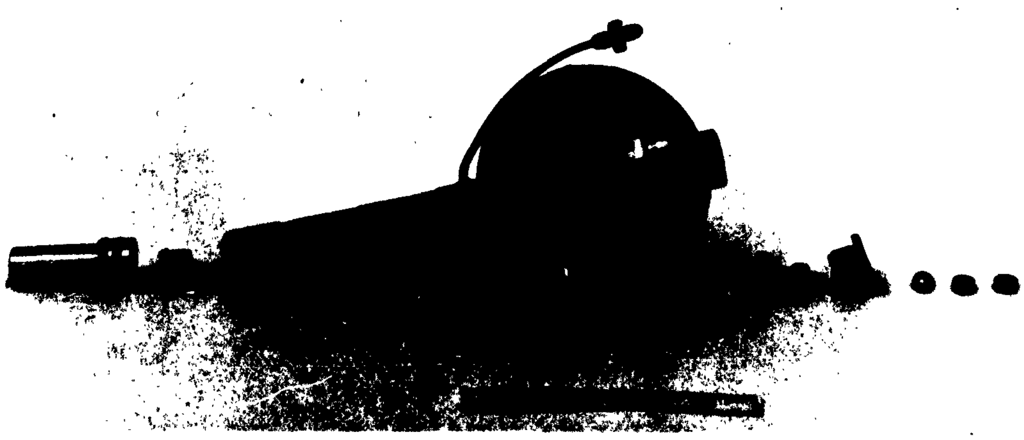


FIG. 4. Actuator and Ejection Assembly Components With Pressure Sphere.

EJECTION ASSEMBLY

Below the actuator assembly, inserted from the bottom of the guide cylinder, is the ejection assembly (Fig. 4), consisting of a piston with a striker on the top (to puncture the actuator piston diaphragm), and a piston cylinder that forms an extension of the guide cylinder when the float is being ejected.

SPOOL ASSEMBLY

The spool assembly consists of an aluminum spool on which the nylon connecting line is stored. The length and tensile strength of the line selected depends on the ocean bottom depth (Table 1). The spool is assembled over the lower portion of the guide cylinder and is free to rotate.

BALLOON ASSEMBLIES

Balloons, secured to bosses, are installed on the fittings of the pressure-vessel outlet tubes, completing the float part of the system. Figure 5 shows the completed assembly with the ejection piston extended from the bottom of the guide cylinder and the spool pulled out slightly to show the nylon line.

GUIDE-POST ASSEMBLY

The guide post and an encircling flange are constructed integrally with a circular base (Fig. 6). This component is bolted into the bottom of the float well in the exercise head so that the base forms a portion of the exercise head section's exterior curved surface. (See Fig. 8, page 9.)

CABLE ASSEMBLY

The cable assembly consists of a 9-foot steel cable with a yoke on one end and a spear compatible with the Retriever Mk 1 Mod 0 on the other end (Fig. 6). The yoke is bolted to the flange around the guide post and the nylon line is attached to the spear with an eye splice (Fig. 7), thus connecting the float assembly to the torpedo (Fig. 8).

LID ASSEMBLY

The lid assembly, which retains the float in the exercise head well and releases it at system actuation, consists of the lid and two retaining rods. The lid, like the guide-post base, is curved to form a part of the exercise head's exterior surface (Fig. 9). The rods incorporate springs that release the lid when the system is actuated.

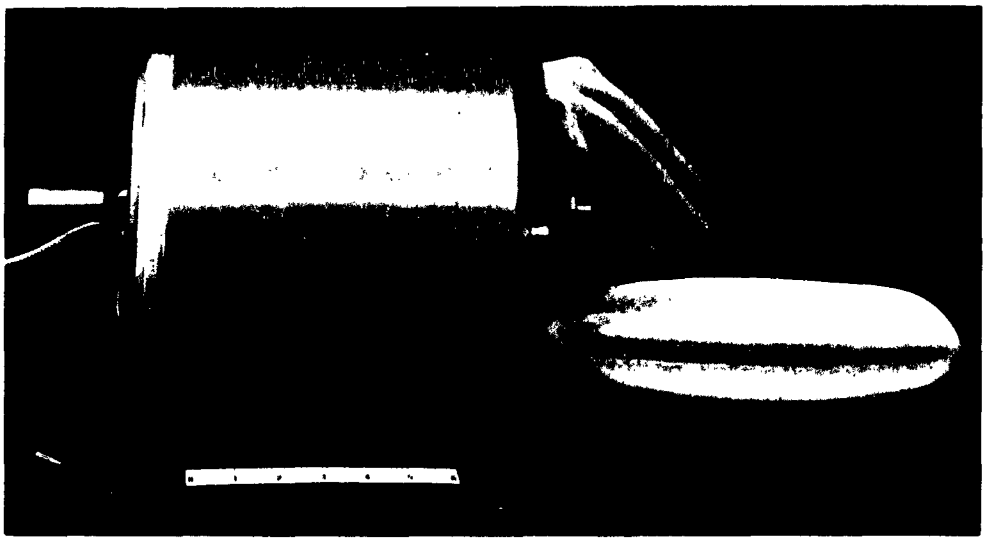


FIG. 5. Assembled Float With Spool Showing and Ejection Piston at Bottom of Guide Cylinder.

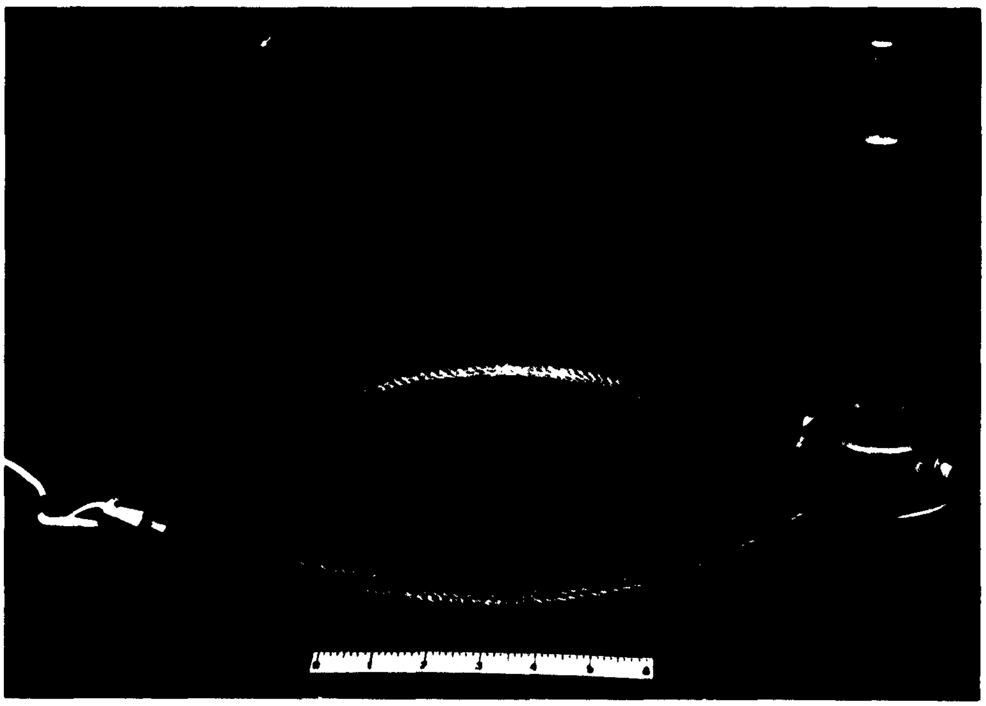


FIG. 6. Guide Post, Cable, and Spear.

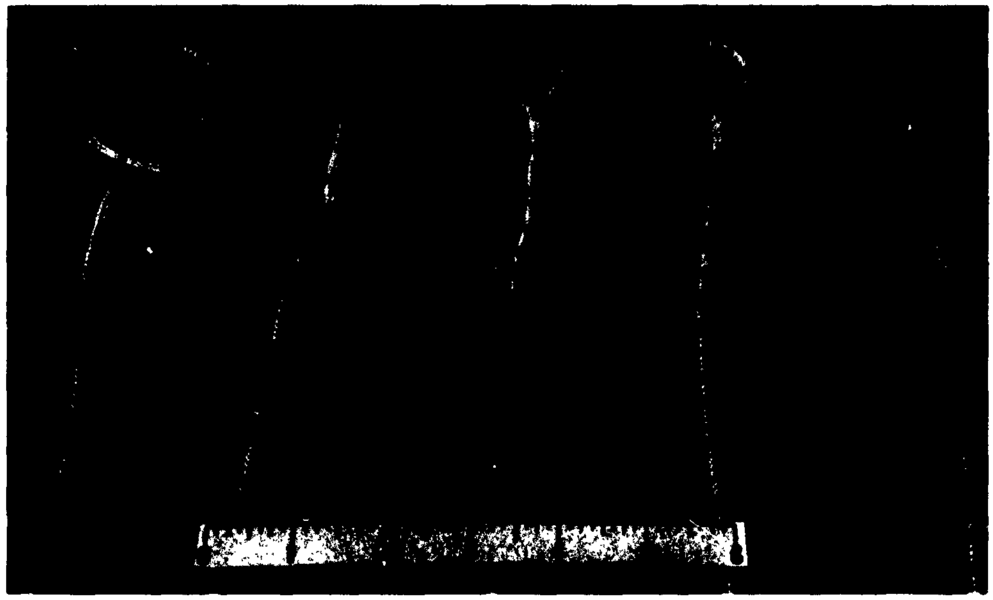


FIG. 7. Eye Splice for Attaching Nylon Line to Spear.

FIG. 8. Float (With Ejector Piston Extended) Ready To Be Installed Into Torpedo.

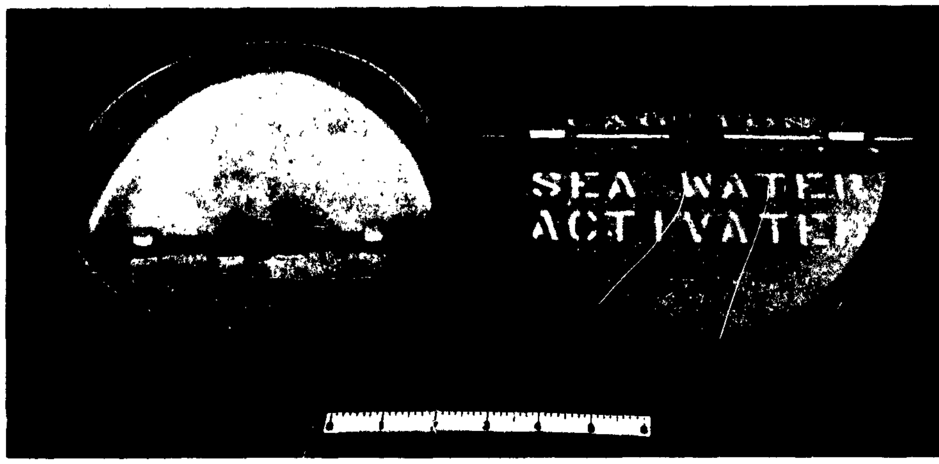


FIG. 9. Interior and Exterior Views of Lid Showing Retaining Rods and Spanner Wrench.

SYSTEM ASSEMBLY AND OPERATION

Filling the pressure sphere with nitrogen for the selected operating depth (Table 1) can be accomplished any time after the float is assembled and before the lid is placed over it in the well. The pressure should be checked with a torque wrench. It may be checked through the center access hole after the lid is in place.

However, the pressurization process should take place several hours before the float is installed in the well, to permit checking for leaks. The addition of a safety nut on top of the first retaining nut on the actuator piston stud after pressurization is considered mandatory for personnel safety.

After the float is connected to the torpedo by the cable assembly, the cable is coiled in the bottom of the exercise head well and the guide cylinder is placed over the guide post as the float is lowered into the well (Fig. 10). The marker balloons are then folded on top of the protective can (Fig. 11). Made of heavy latex rubber (weighing more than 90 grams each), the balloons are fluted to facilitate folding and to minimize the possibility of localized air pockets during inflation.

The safety nut is now removed and the lid positioned in the well. A spanner wrench inserted through the outer access holes of the lid (Fig. 9) compresses the retaining rod springs so that the rods are forced apart from the center and the opposite ends are positioned into recesses in the well. Through the middle access hole, the second retaining nut is screwed on the actuator piston stud to hold the rods

FIG. 10. Float Being Lowered Into Well.

FIG. 11. Balloons Folded on Top of Float.

apart (Fig. 12). When the wrench is withdrawn, the system is ready to actuate (Fig. 13).

As shown in Fig. 14, compressed nitrogen is present around the throat of the actuator piston. The magnesium-alloy disk is the only thing that restrains the actuator from being retracted downward by the differential between the upper and lower piston areas upon which the pressure is acting. When sea-water action sufficiently corrodes the disk, the actuator piston retracts downward, pulling the second retaining nut from between the lid retaining rods. Spring action forces the rods together so that the opposite ends are free of the rod holes in the float well, and the lid is released.

Immediately thereafter, the diaphragm in the bottom of the actuator piston is punctured as it hits the striker on top of the ejection piston that is resting on the guide post. The compressed nitrogen is released through the punctured diaphragm into the guide cylinder and commences to force the float upward. As the guide cylinder travels up the guide post, a retaining ring at the bottom of the guide cylinder engages the shoulder of the ejection piston cylinder. The guide cylinder then pulls the ejection piston cylinder upward until a retaining ring in the lower end of the ejection piston cylinder bore engages the bottom of the ejection (striker) piston. The ejection piston is now at the bottom of the ejection piston cylinder, forming an extension of the guide cylinder. This added cylinder length is necessary to free the float by forcing it clear of the well and of the guide post.

The nylon line is reeled off the spool and, as the water pressure decreases, the balloons expand, providing additional buoyancy. The balloons are inflated to a spherical shape and, depending on the gas pressure used, reach a diameter of from 14 to 24 inches. They rise to the water surface and become large sighting markers that can be seen half a mile away.

If the negative buoyancy of the torpedo is less than one-half the breaking strength of the nylon line (Table 1), the torpedo can be retrieved by hauling in the line, with a torque-limiting winch controlling the tension. Otherwise, the line is placed in the Retriever Mk 1 Mod 0 (Fig. 15) and the torque-limiting winch is used to control the tension on the nylon line. The retriever, attached to one end of a steel cable, descends the line by gravity until it connects with the compatible spear (Fig. 16) to form a continuous steel cable from the torpedo to the recovery boat. The steel cable should be reeled in with a cable winch.

PERFORMANCE TRIALS

Performance demonstrations consisted of (1) system functioning tests, (2) launch shock tests, and (3) tests to simulate a running torpedo environment. (Laboratory tests on component design, selection, and reliability are not reported here.)

FIG. 12. Second Retaining Nut Being Placed Between Lid Retaining Rods.

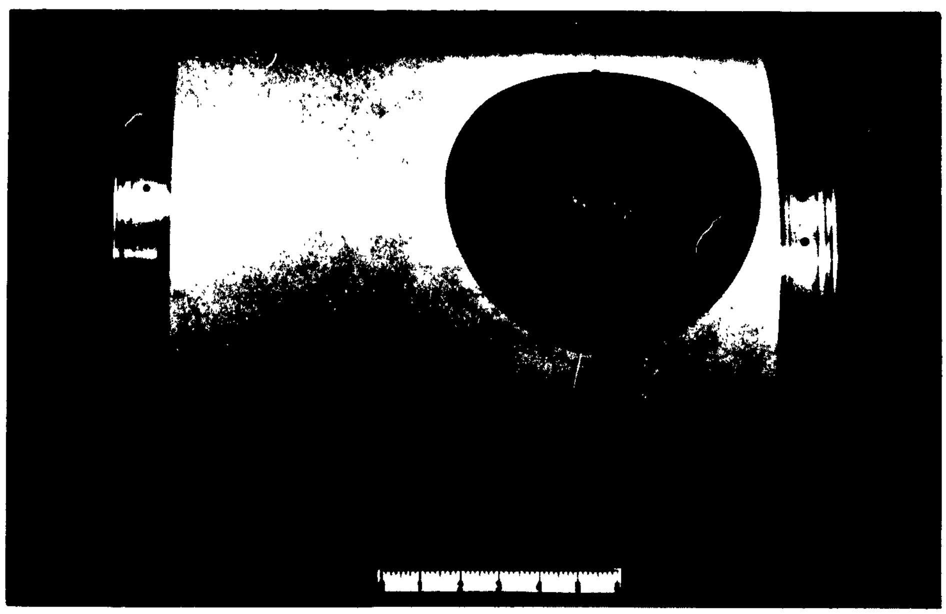


FIG. 13. Float Ready To Actuate.

SYSTEM FUNCTIONING

Ten tests were conducted at sea before the Gas-Ejected Float and Recovery System was used in a research vehicle configuration. The float was placed in an exercise-head section or a dummy torpedo and dropped to the ocean floor. In each case, the float surfaced with the line attached and the exercise head or dummy torpedo was retrieved without diver assistance.

Twice, using a 200-pound negatively buoyant dummy torpedo, divers positioned the torpedo in relation to the ocean floor, first with the float lid at 180 degrees from top vertical, and second at 135 degrees from top vertical. In both instances, the float ejected with sufficient force to roll the dummy torpedo over, free itself, and rise to the surface with all components functioning properly.

LAUNCH SHOCK TESTS

Aircraft and Rocket Launchings (Simulated)

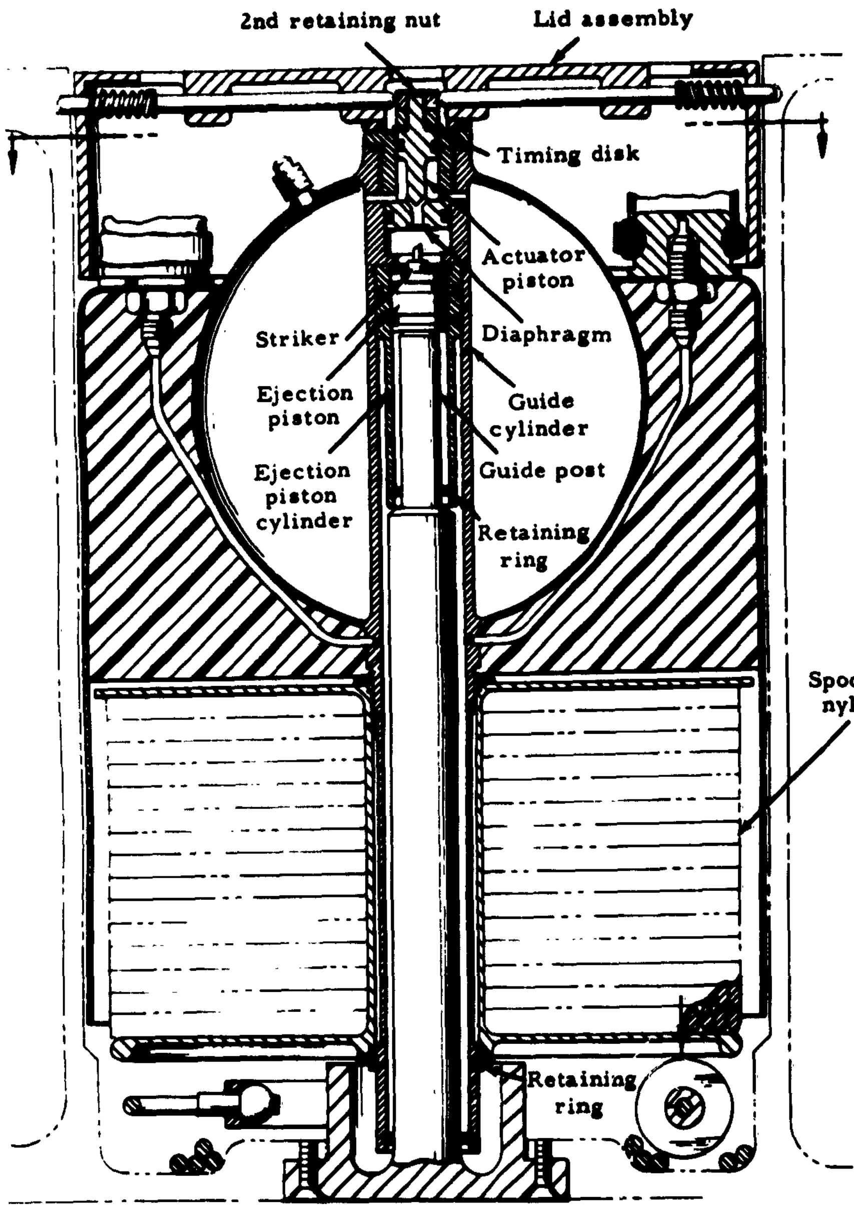
Tests at Morris Dam on the Variable-Angle Launcher and the Small-Caliber (Sling-Shot) Range simulated aircraft and rocket-launched shock loads. For these tests the float system was installed in a dummy developmental torpedo.

On the Variable-Angle Launcher test, simulating an aircraft launching, the dummy torpedo entered the water at an angle of 12.5 degrees from horizontal at 185 fps. Water entry from the Sling-Shot, simulating a rocket launching, was at an angle of 89.8 degrees from horizontal at 169 fps. The latter test was conducted without a nose cap on the dummy torpedo, which, if it had been used, would have absorbed part of the water-entry shock.

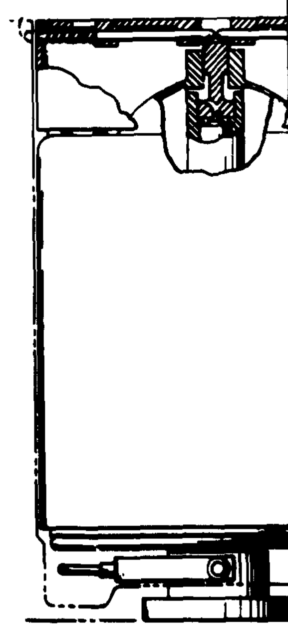
The dummy torpedoes were recovered from the fresh water and transported to the Long Beach Range to be submerged in salt water. Float ejection and operation of all system components were entirely satisfactory.

Torpedo Tube Mk 32 Launchings

The float system was installed in dummy developmental torpedoes for the four Torpedo Tube Mk 32 launchings. The system operated normally and retrieval was effected by either the connecting line or the continuous steel cable when the Retriever Mk 1 Mod 0 was used.



Cutaway of float assembly before actuation



First step in actu

FIG.

1

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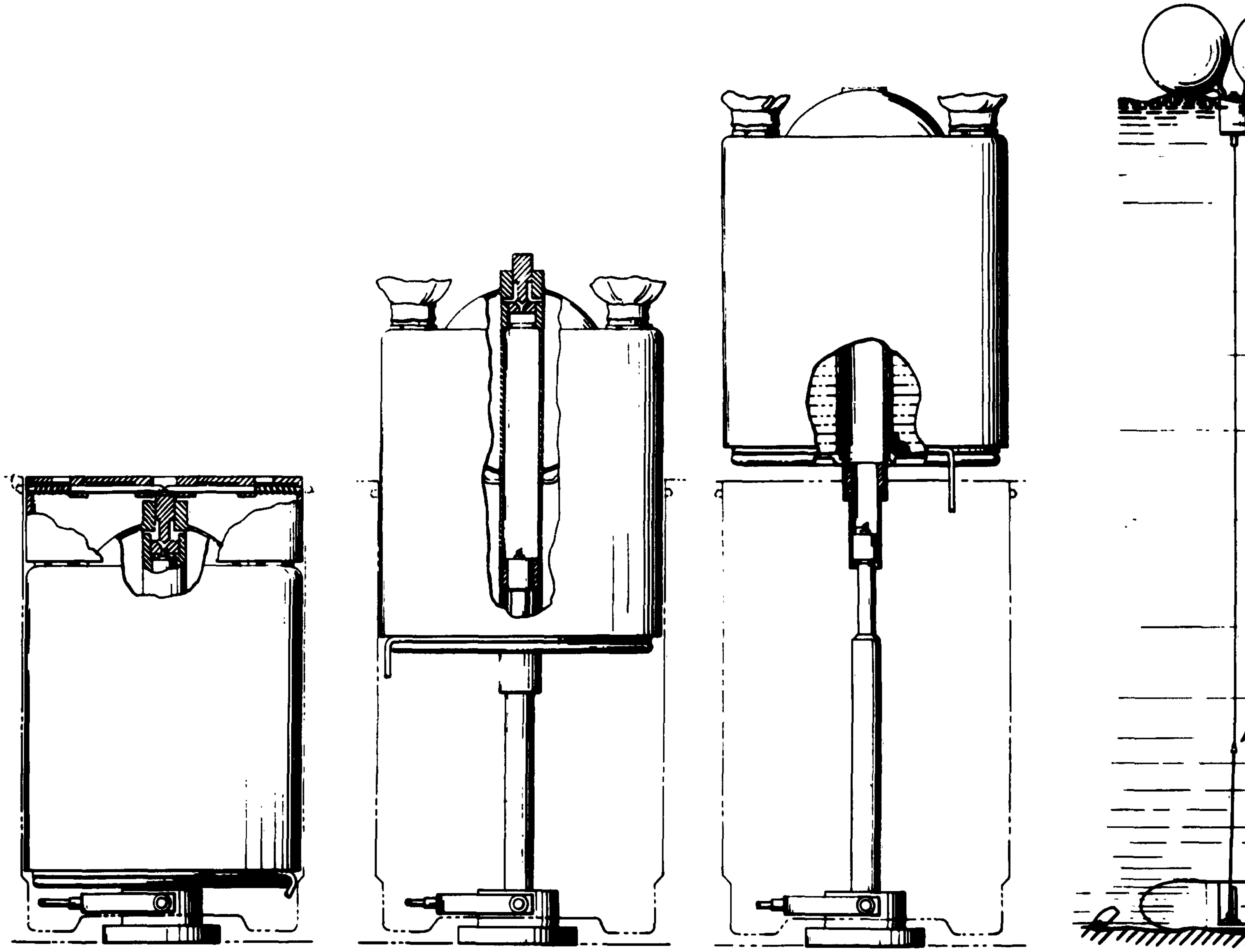
line



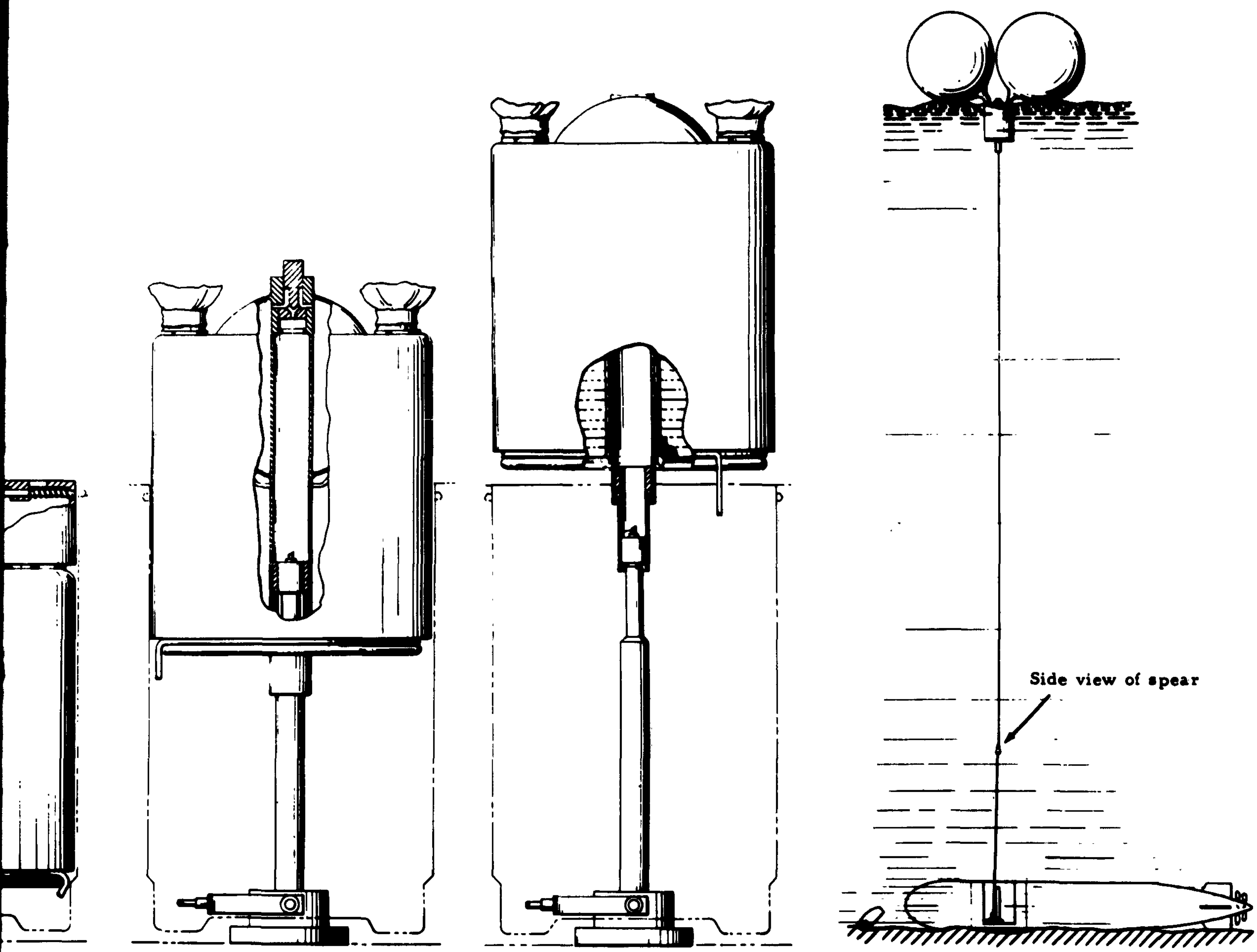
First step in actuation

Partially out of well

Completely out of well

Complete sy

FIG. 14. Float System Actuating.



14. Float System Actuating.

3

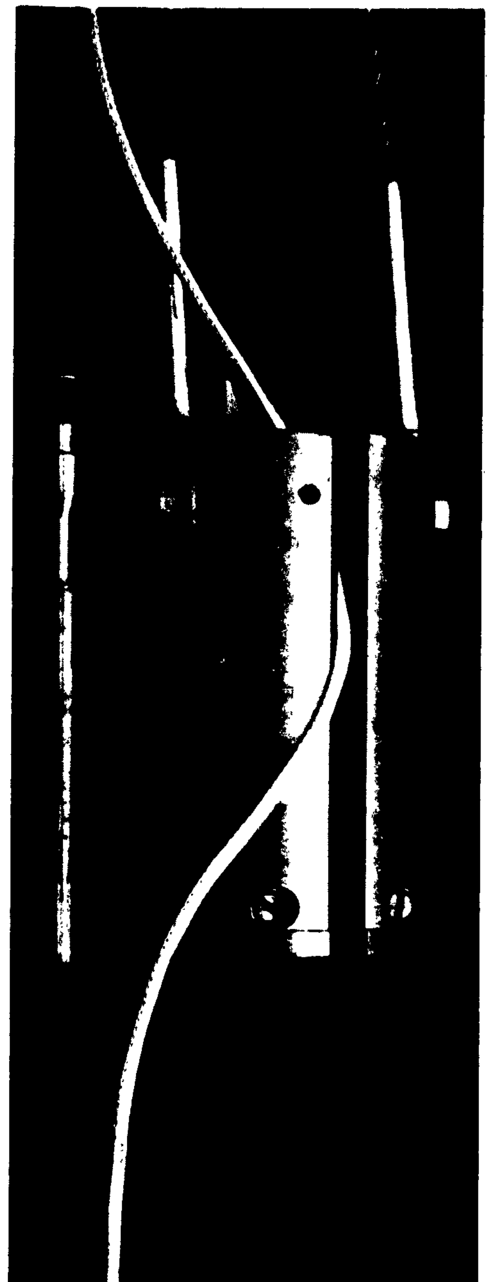


FIG. 15. Nylon Line Being Placed in Retriever Mk 1 Mod 0. (Retainer shown removed.)

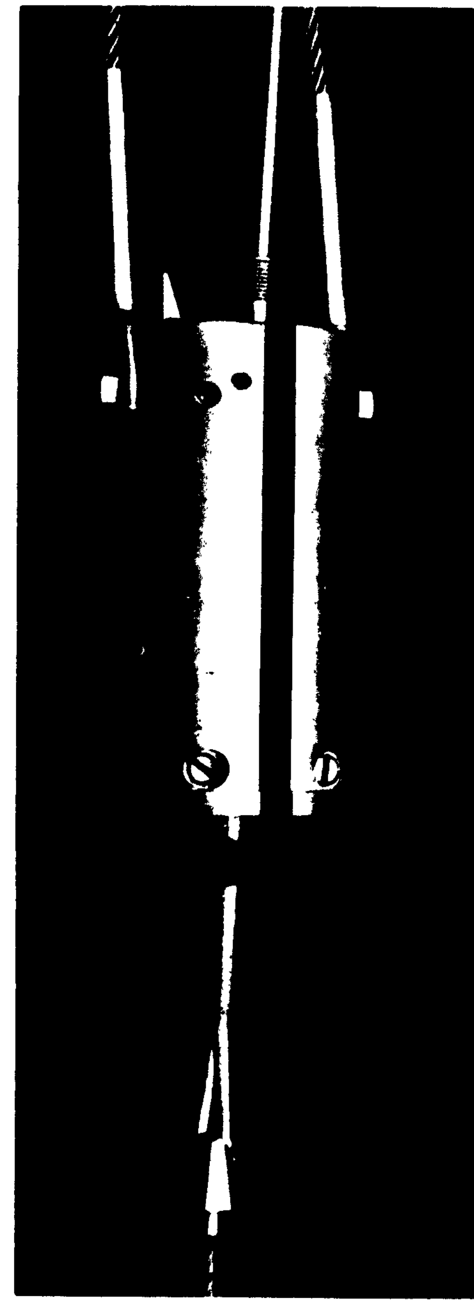


FIG. 16. Retriever Mk 1 Mod 0 Just Before Spear Is Joined to It.

TESTS SIMULATING A RUNNING TORPEDO ENVIRONMENT

The float system, assembled in ready condition into an exercise-head section, was subjected to the vibration conditions specified in MIL-T-18404 for an operating torpedo. During the 15-minute tests that were conducted in each of three mutually perpendicular axes for a total of 45 minutes, 1g of vibration was applied at rates from 20 to 150 cps during 3- to 5-minute sweep periods.

After the tests, the float system was disassembled and inspected. All components were found to be in pre-test condition.

OPERATIONAL USE

TESTS IN RESEARCH VEHICLE CONFIGURATION

A NOTS research vehicle incorporating the float system was launched 25 times from the Torpedo Tube Mk 32. In all but three instances, float operation and surfacing were satisfactory and the vehicles were recovered.

A failure occurred when one of the balloons became detached before the float surfaced. Buoyancy from the remaining balloon caused the float to cock and the nylon line stopped reeling out. Modifications of the balloon attachments, and of the spool to permit it to rotate, if necessary, have since been incorporated to prevent a recurrence of this malfunction.

Test photographs show that the second failure was caused by the float-well lid becoming unlocked on one side prior to water entry. After water entry, the lid came off, permitting the float to leave the torpedo without being actuated. The unoperated float surfaced without the added buoyancy of the inflated balloons and with most of the nylon line (severed by the running torpedo) still on the spool. Post-run examination of the torpedo revealed that wear in the exercise head holes that house the lid retaining rods had permitted the rods to shift to one side at launch shock and release the lid. Steel inserts are now installed in the exercise head holes.

In the third failure, the lid did not release and the torpedo had to be recovered by divers. Post-run examination indicated that there must have been a slow leak in the actuator piston before the diaphragm was punctured, causing such pressure against the lid retaining rods that they could not release. If the pressure sphere is charged with nitrogen several hours before it is installed in the torpedo, as is now standard practice, the ejection piston assembly can be checked for movement down the guide piston, which would indicate leakage in the area that caused this failure.

TESTS IN DEVELOPMENTAL TORPEDO

Rocket Launchings. In two rocket launchings with the float system installed in the developmental torpedo, recovery was successful. The second recovery was made from a 320-foot bottom, beyond diver-operating depth.

Slide Launchings. All other launchings of the developmental torpedo using the float system (15) were made from a slide launcher. The float system operated satisfactorily except on two occasions. In one instance, the timing disk was mechanically sheared inadvertently while the lid-locking wrench was in place, thus locking the lid and preventing ejection. The torpedo was launched with the float system in this non-operating condition. On the other occasion, the torpedo was lost following an impact on a target.

EXTENSION OF DEPTH AND RECOVERY CAPABILITIES

Tests with the Gas-Ejected Float and Recovery System in a dummy torpedo are being continued to confirm its depth capabilities.

On the deepest test, conducted at 2,600 feet with an extra line on the dummy torpedo for safety, the float ejected but did not surface. It was sighted as the vehicle was being raised by the steel cable carried down the safety line by the Retriever Mk 1 Mod 0. The retriever engaged the spear at the bottom on the first attempt, a significant demonstration of Retriever Mk 1 Mod 0 performance at this depth. Although the float system ejected properly, the amount of nylon line being carried was apparently insufficient to allow the float to surface because of a greater depth than was planned.

CONCLUSIONS AND RECOMMENDATIONS

The Gas-Ejected Float and Recovery System reliably retrieved 185-pound negatively buoyant vehicles from beyond diver-operating depths. The float functioned to 2,600 feet and although the 3,000-foot requirement was not met, the major limitation appeared to be the length of nylon line that could be carried. The system performed satisfactorily after slide, tube, and rocket launchings and a simulated aircraft launching. The system was operational in June 1961, 5 months after project assignment.

The Retriever Mk 1 Mod 0, incorporated as an accessory for the system, was lowered on a connecting line to 2,600 feet and successfully engaged the spear to recover a dummy torpedo. No previous record of this component operating successfully to such a depth is available.

The Gas-Ejected Float and Recovery System operation is independent of all vehicle functions and does not restrict the degree of negative buoyancy.

A space limitation dictated the present size and configuration of the float system. It is believed that the concept of a self-contained unit should remain unchanged, but that size and configuration could be modified to adapt to lesser or greater space allocations. Larger vehicles, such as practice mines, could accommodate a float system carrying a connecting line of sufficiently high strength to eliminate the use of the Retriever Mk 1 Mod 0 and thus expedite operations.

Appendix

BACKGROUND OF COMPONENT SELECTION

To obtain the performance desired in the float system, a number of alternate methods or materials were considered for timing, ejection and buoyancy, retention and release, and recovery.

To provide reliable timing, it was necessary to find a mechanism that would function regardless of torpedo performance. Pyrotechnic timing devices were not feasible because an electric power source is required for ignition, and would occupy more space than is practical. Such water-soluble materials as Gelvatrol and salt tablets were considered, but Gelvatrol lacks mechanical strength, salt tablets vary in rate of erosion according to the velocity of water flow, and both are unstable under humid conditions. After investigation of electrolytically corrosive materials, a magnesium-alloy disk was selected for its mechanical strength and fast, predictable corrosion rate in sea water, and because the timing could be varied by the disk dimensions.

The method to be used for float ejection had to assure sufficient force to free the float from the torpedo regardless of its orientation on the ocean floor. In addition to the pneumatic method selected, pyrotechnic and mechanical methods were also considered. The first was rejected because it involved a propellant grain for gas generation and an electric power supply for ignition. The second, involving a compressed spring to provide ejection force, required too large a spring for the available space.

For the buoyancy necessary to bring the float and connecting line to the surface from maximum depths, a syntactic epoxy foam filler proved most satisfactory in providing maximum displacement and strength-to-weight ratio.

It was necessary that the device developed to retain the float in the torpedo withstand the shock loads of all modes of launching, yet release reliably and quickly upon system actuation. Because compressed O-rings and similar devices had been found unsatisfactory in providing positive lock, the spring-loaded rod concept was devised to hold the lid in place.

Many materials were considered for the connecting line. Nylon was selected for its strength-to-weight ratio, flexibility, and ready

availability in required lengths and test strengths. A spool was chosen to store the line because (1) it provides storage for the most line in the least space, (2) it is adaptable to all weights of line, (3) it does not require a special wrapping, and (4) it provides a simple method of reeling out the line as the float rises.

The balloons were added to take advantage of the compressed nitrogen as it ejected the float. They provided a bonus of buoyancy as well as a means of easier surface sighting.

A weakness was revealed when it was found that the nylon line would break inside the knot that connected it to the spear. The failures occurred at 50 to 60% of the tensile strength of the line, wet or dry. Experimentation with several types of knots revealed that the eye splice now used (Fig. 7) has an attachment strength equal to 95% of the line strength, wet or dry.

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ABSTRACT CARD

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NAVWEPS Report 8091

ABSTRACT. The retrieval of negatively buoyant exercise torpedoes from the ocean floor after sea-run tests is essential to the antisubmarine-warfare effort. A simple, self-contained nonelectrical recovery system carried in the torpedo exercise head is described. It includes a gas-ejected float that has surfaced from varying depths to 2,600 feet, bringing up a connecting nylon line and two marker balloons. Electrolytic corrosion of a magnesium-alloy disk provides the timing from launching to positive ejection. The accessories for recovery include the Retriever Mk 1 Mod 0 and a torque-limiting winch.

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